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EDGE GRADIENT RESOLUTION MEASUREMENTS USING SPECIAL MICROSCOPE.(U)
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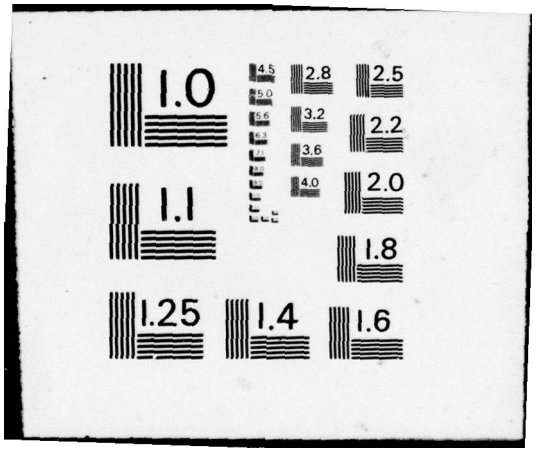
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EDGE GRADIENT RESOLUTION MEASUREMENTS USING SPECIAL MICROSCOPE

Dynamics and Environmental Evaluation Branch
Reconnaissance and Weapon Delivery Division

November 1975

TECHNICAL REPORT AFAL-TR-75-97

Final Report for Period January 1975 - April 1975

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AIR FORCE AVIONICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
Air Force Systems Command
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Edward L. Gliatti

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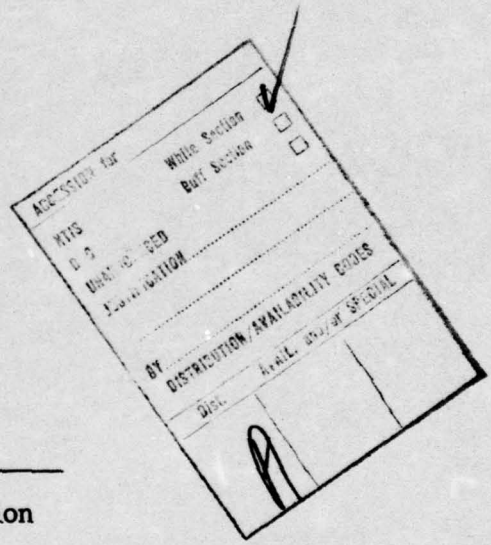

FOR THE COMMANDER

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Field evaluations of imagery can be performed simply, quickly, and with results accurate to three elements when compared to three bar targets results. These results occur when targets with resolution less than 100 line pairs per millimeter are examined. The method employed is edge gradient measurements using a special microscope manufactured by Gaertner Scientific Corp. Easier measurements could be made if the target comparison reticle were redesigned.

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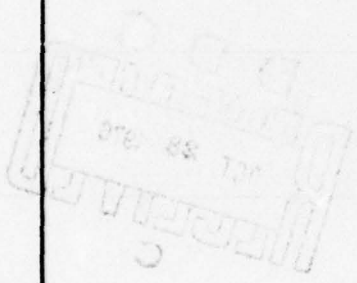

FOREWORD

This report was written by Edward L. Gliatti of the Dynamics and Environmental Evaluation Branch (AFAL/RWF-2), Reconnaissance and Weapon Delivery Division, Avionics Laboratory, Wright-Patterson Air Force Base, Ohio. This report was performed under Work Number 20040516 entitled "Reconnaissance and Weapon Delivery Sensor system and Imagery Analysis."

The research of the report was performed from January 1975 to April 1975.

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SECTION I

INTRODUCTION

At the twelfth meeting of the Photographic Reconnaissance Equipment Advisory Group (PREAG) in September 1973, MSgt. Tony Pollizzi presented a paper on the method of determining photographic system resolution by edge gradient measurements. The exploration of this technique was encouraged by the need for a simple method to evaluate imagery at the field level. His criteria included a fairly accurate resolution measurement having day-to-day consistency, requiring a minimum amount of time to perform the actual measurements and resolution determinations, and providing the capability to obtain ground resolution readings without scheduling special flights over a bar target range.

Prototype microscopes have been manufactured by Gaertner Scientific Corporation that provide edge gradient imagery analysis. The device essentially consists of a measuring microscope with a range of magnification of 40X-100X and a 1951 USAF target mounted on a rotatable reticle located in the barrel of the microscope.

At this PREAG meeting, it was recommended that Air Force Avionics Laboratory (AFAL) purchase one of these microscopes to evaluate this method. Subsequently, this became an action item under the Sentinel Sigma program and a measuring microscope similarly equipped was purchased from Gaertner Scientific Corporation by AFAL. The unit mounted on a Richard's light table is shown in Figure 1. This arrangement with the microscope cantilevered from the moveable slide was established to allow a simple set up where the unit could be interchanged easily with the Bausch and Lomb microscope. However, the arrangement was not rigid causing focus shift problems when slight force was applied to the set up. This shifting and the absence of a fine focus adjustment caused considerable problems. However, with care and patience in reading the targets, this problem was reduced. Future implementations should consider a more stable and rigid mounting arrangement and a fine focus adjustment as requirements for any anticipated deployment.

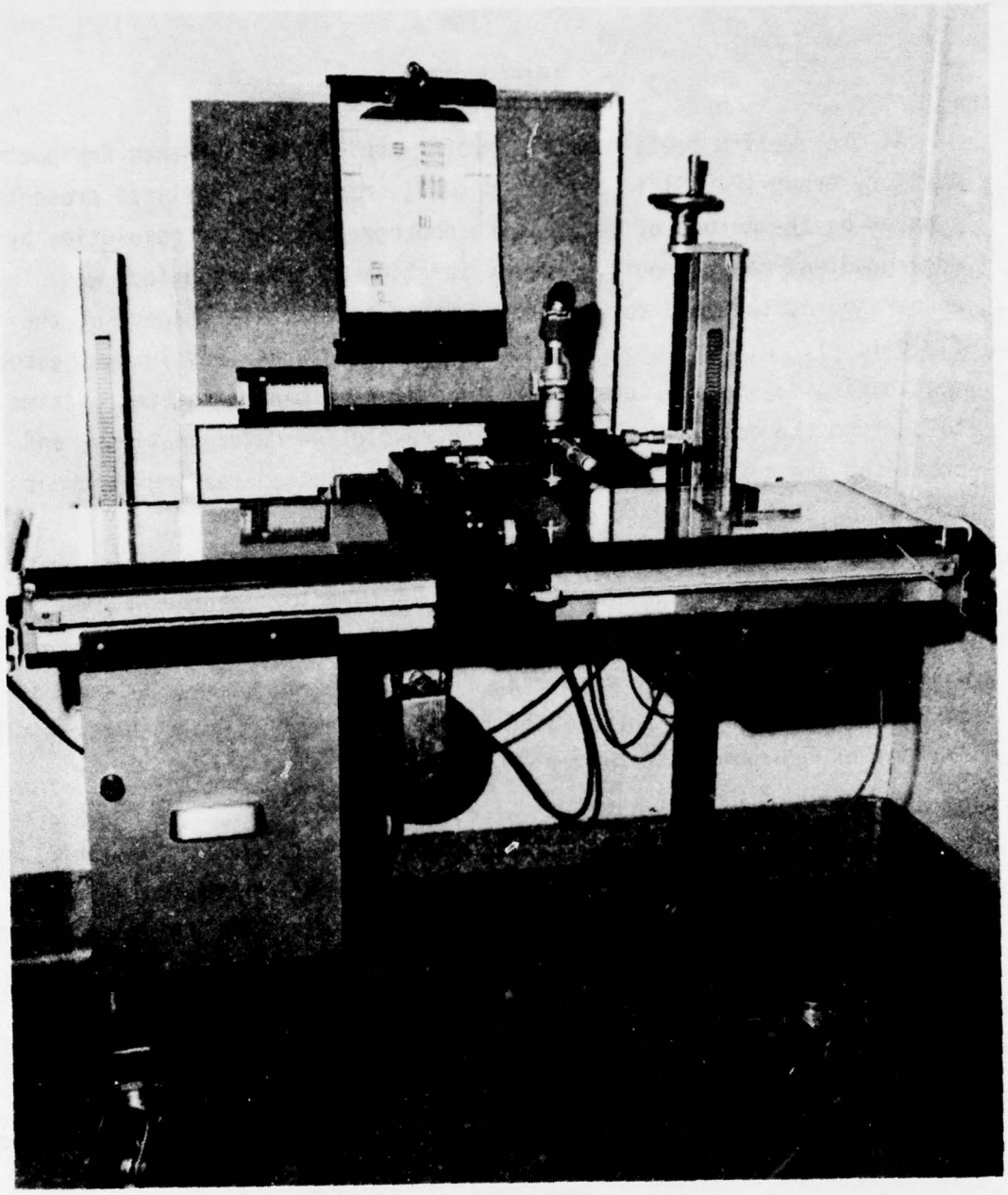

Figure 1. The Edge Gradient Image Analysis Microscope Mounted on a Richard's Light Table

Efficient operation of the unit requires a reasonable degree of training. During the AFAL test, nine different readers were used with experience ranging from very little to extensive. One reader spent more than 40 hours training in the use of this technique investigating various methods of reading targets. All other observers had a nominal hour indoctrination before reading targets. The results of the nine including the one especially trained are reported herein.

SECTION II

TEST DISCUSSION

The basic concept in using this device is to match the estimated width of a target edge with a bar or space on the three bar target reticle located in the microscope. The target element is noted and the resolution is determined from a table supplied with the microscope. Readers differed considerably on what they preferred to match in the target reticle; a space, a bar, or a space-bar combination. The expert reader preferred to match bars. In the event, both a bar and space are matched to the edge the resulting resolution value must be doubled to yield the correct number.

For the test, 84 medium contrast and 6 low contrast targets were measured. Figure 2 shows the layout of seven of the medium contrast targets. The six low contrast targets were similar except that there was only one target per frame. The expert observer read all 90 targets; however, the other eight observers read only 12 targets selected from the 90. These targets were selected to give three approximate ranges of resolution: four high resolution targets (above 100 line pair/mm), four medium resolution targets (75 to 100 line pair/mm), and four low resolution targets (less than 75 line pair/mm), with each range having two medium (5.6:1) and two low (1.4:1) contrast targets. The resolution data for the nine observers reading the targets using the usual three bar method and the edge gradient method are listed in Table 1. Shown are each individual's readings for both the tangential and the radial directions, the average of the readers, and the standard deviation among the readers for every target. In calculating these averages and deviations, any observation that deviated by more than 50% from any other reading in the group was eliminated.

A summary of the test results is shown in Table 2. There the group averages, the standard deviation, and the three bar element differences corresponding to the standard deviations are presented. The nine observers deviated less than two resolution target elements using the standard three

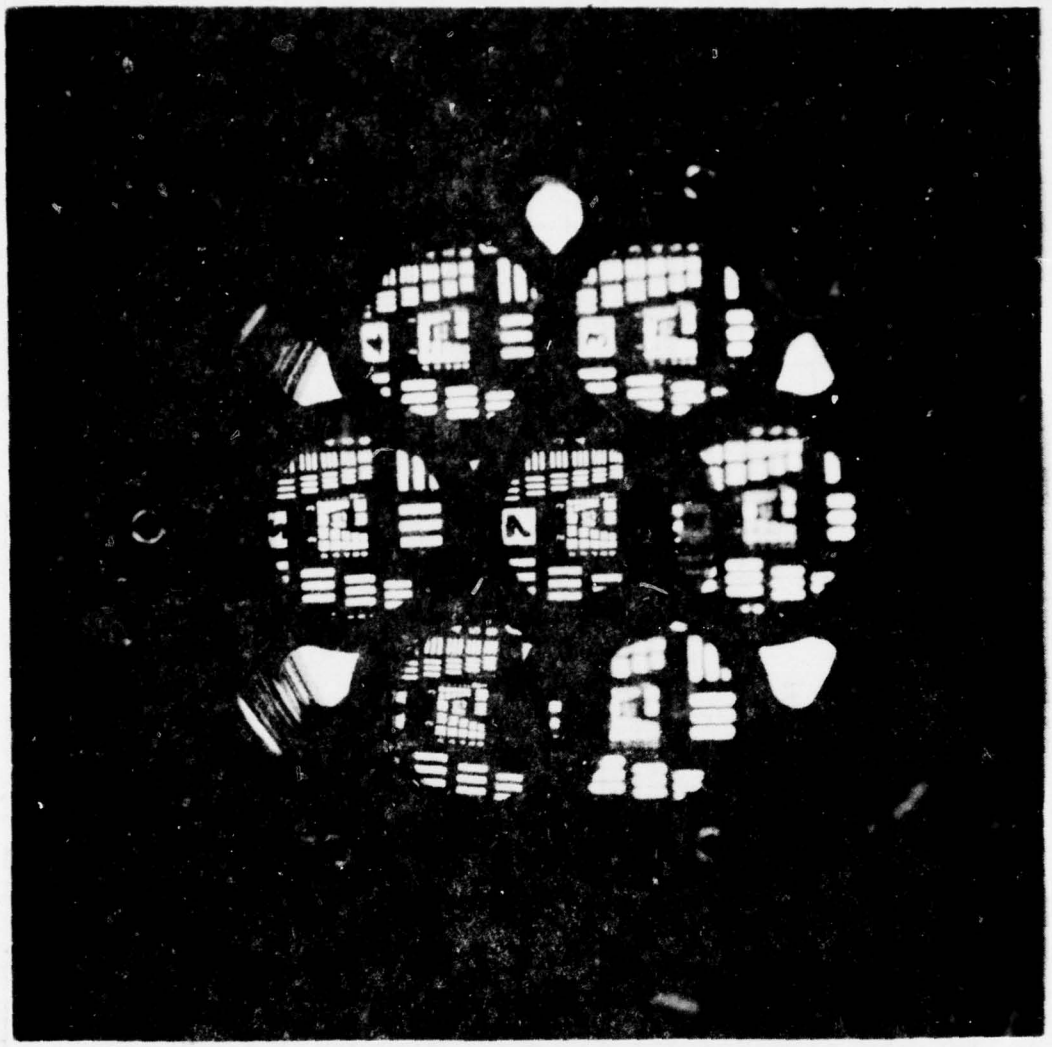

Figure 2. Layout of the Targets

TABLE 1

RESOLUTION READINGS FOR ALL NINE OBSERVERS (LP/MM)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
#1 CONTRAST 5.6:1 RESOLUTION Low	1	56.9	56.9	59.6	53.3	#3 CONTRAST 5.6:1 RESOLUTION Medium	1	90.2	90.2	95.0	95.0
	2	45.1	50.8	67.3	53.3		2	80.6	80.6	84.6	75.3
	3	35.8	35.8	67.3	42.3		3	50.8	50.8	84.6	75.3
	4	40.3	40.3	59.6	42.3		4	128.0	143.5	84.6	75.3
	5	50.8	50.8	59.6	53.3		5	128.0	128.0	134.3	119.3
	6	56.9	56.9	84.6	84.6		6	90.2	80.6	106.6	134.3
	7	56.9	56.9	47.3	42.3		7	90.2	71.7	75.3	75.3
	8	50.8	50.8	67.3	59.6		8	90.2	71.7	95.0	134.3
	9	40.3	45.1	59.6	47.3		9	56.9	45.1	75.3	75.3
	AVERAGE	48.20	49.37	63.58	53.14		AVERAGE	89.47	84.69	92.81	95.49
	SIGMA	8.13	7.59	10.07	13.31		SIGMA	26.47	32.50	18.50	26.50
#2 CONTRAST 5.6:1 RESOLUTION Low	1	56.9	56.9	29.6	29.6	#4 CONTRAST 5.6:1 RESOLUTION Medium	1	71.7	80.6	75.3	84.6
	2	56.9	56.9	33.6	18.6		2	114.0	114.0	84.6	75.3
	3	32.0	32.0	42.3	29.6		3	64.0	64.0	75.3	95.0
	4	90.2	90.2	18.7	21.3		4	143.5	161.0	67.3	84.6
	5	50.8	40.3	21.3	29.6		5	101.8	101.8	84.6	106.6
	6	45.1	40.3	33.6	37.6		6	64.0	56.9	95.0	106.6
	7	56.9	64.0	16.6	15.0		7	71.7	90.2	75.3	95.0
	8	45.1	40.3	29.6	33.6		8	114.0	101.8	84.6	84.6
	9	56.9	40.3	42.3	33.6		9	90.2	101.8	84.6	106.6
	AVERAGE	50.08	46.38	29.73	27.61		AVERAGE	92.77	96.90	80.73	93.21
	SIGMA	8.97	11.25	9.43	7.61		SIGMA	27.63	30.55	8.16	11.66

TABLE 1 (Cont'd)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
#5 CONTRAST 5.6:1 RESOLUTION High	1	128.0	114.0	189.6	150.3	#7 CONTRAST 1.4:1 RESOLUTION Low	1	56.9	64.0	53.3	67.3
	2	227.0	227.0	189.6	134.3		2	35.8	35.0	67.3	67.3
	3	256.0	256.0	189.6	134.3		3	32.0	32.0	53.3	67.3
	4	56.9	80.6	119.3	106.6		4	64.0	71.7	47.3	53.3
	5	181.0	143.5	213.3	189.6		5	80.6	101.8	59.6	67.3
	6	80.6	128.0	119.3	106.6		6	40.3	56.9	67.3	84.6
	7	143.5	128.0	29.6	75.3		7	128.0	128.0	59.6	67.3
	8	114.0	101.8	169.3	134.3		8	45.1	45.1	47.3	59.6
	9	50.8	40.3	134.3	119.3		9	50.8	56.9	59.6	59.6
	AVERAGE	137.53	147.36	165.54	127.88		AVERAGE	53.36	65.71	57.18	65.96
	SIGMA	72.35	61.59	36.42	31.98		SIGMA	16.13	31.39	7.48	8.64
#6 CONTRAST 5.6:1 RESOLUTION High	1	101.8	90.2	134.3	134.3	#8 CONTRAST 1.4:1 RESOLUTION Medium	1	80.6	64.0	84.6	67.3
	2	56.9	114.0	106.6	119.3		2	128.0	128.0	84.6	67.3
	3	128.0	64.0	119.3	119.3		3	64.0	64.0	84.6	67.3
	4	50.8	56.9	84.6	106.6		4	80.6	64.0	67.3	67.3
	5	161.0	101.8	150.3	150.3		5	101.8	128.0	95.0	67.3
	6	227.0	114.0	119.3	106.6		6	50.8	45.1	95.0	67.3
	7	128.0	101.8	119.3	106.6		7	203.0	143.5	95.0	75.3
	8	114.0	90.2	106.6	106.6		8	64.0	64.0	75.3	59.6
	9	40.3	45.1	119.3	119.3		9	80.6	71.7	67.3	67.3
	AVERAGE	111.98	86.44	117.73	118.77		AVERAGE	85.66	85.81	83.19	
	SIGMA	59.34	25.26	18.34	15.11		SIGMA	22.01	36.48	11.13	

TABLE 1 (Concluded)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	TGT. #	READER #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
#9 CONTRAST 1.4:1 RESOLUTION High	1	80.6	80.6	95.0	95.0	#11 CONTRAST 1.4:1 RESOLUTION Low	1	64.0	50.8	53.3	37.6
	2	203.0	203.0	95.0	95.0		2	64.0	64.0	53.3	37.6
	3	64.0	64.0	95.0	95.0		3	56.9	56.9	53.3	37.6
	4	71.7	101.8	67.3	75.3		4	101.8	64.0	53.3	37.6
	5	128.0	101.8	95.0	95.0		5	71.7	64.0	53.3	37.6
	6	64.0	71.7	95.0	95.0		6	71.7	56.9	59.6	42.3
	7	256.0	256.0	95.0	84.6		7	80.6	71.7	47.3	33.6
	8	80.6	80.6	84.6	75.3		8	45.1	45.1	47.3	37.6
	9	80.6	71.7	95.0	95.0		9	50.8	56.9	53.3	42.3
	AVERAGE	114.28	114.58	90.77	89.47		AVERAGE	67.40	58.92	52.67	38.20
	SIGMA	69.30	67.72	9.45	8.72		SIGMA	16.96	7.98	3.68	2.67
#10 CONTRAST 1.4:1 RESOLUTION Medium	1	80.6	80.6	84.6	75.3	#12 CONTRAST 1.4:1 RESOLUTION High	1	101.8	101.8	106.6	106.6
	2	143.5	114.0	84.6	75.3		2	143.5	143.5	95.0	95.0
	3	64.0	64.0	84.6	119.3		3	64.0	64.0	106.6	106.6
	4	101.8	64.0	84.6	75.3		4	181.0	227.0	95.0	84.5
	5	128.0	128.0	106.6	106.6		5	128.0	128.0	150.3	150.3
	6	101.8	90.2	84.6	75.3		6	128.0	128.0	119.3	119.3
	7	227.0	227.0	84.6	67.3		7	227.0	161.0	95.0	95.0
	8	90.2	101.8	84.6	75.3		8	56.9	56.9	95.0	95.0
	9	80.6	71.7	84.6	67.3		9	56.9	50.8	95.0	95.0
	AVERAGE	98.81	89.29	87.04	81.89		AVERAGE	120.79	117.89	106.42	105.27
	SIGMA	26.23	23.70	7.33	18.21		SIGMA	58.39	57.02	18.52	19.61

TABLE 2

TEST RESULTS COMPARING THREE-BAR RESOLUTION READINGS
WITH VISUAL EDGE GRADIENT RESOLUTION READINGS

CONVENTIONAL 3-BAR READING

RADIAL			TANG		
AVG	σ	Δ EL	AVG	σ	Δ EL
63.58	10.07	<2	53.14	13.31	<2
29.73	9.43	<3	27.61	7.61	<3
57.18	7.48	<2	65.96	8.64	<2
52.67	3.68	<1	38.20	2.67	<1
92.18	18.50	<2	95.49	26.50	<3
80.73	8.16	<1	93.21	11.66	<2
83.19	11.13	<2	67.33	3.93	<1
87.04	7.33	<1	81.89	18.21	<2
165.54	36.42	<2	127.88	31.98	<2
117.73	18.34	<2	118.77	15.11	<2
90.77	9.45	<1	89.47	8.72	<1
106.42	18.52	<2	105.27	19.61	<2

VISUAL EDGE GRADIENT READING

RADIAL			TANG				
AVG	σ	Δ EL	AVG	σ	Δ EL		
48.20	8.13	<2	49.37	7.59	<2	LOW RESOL ≤74 LP/MM	MED CONTRAST
50.08	8.97	<2	46.38	11.25	<2		
50.69	16.13	<3	65.71	31.39	<4		LOW CONTRAST
67.40	16.96	<2	58.92	7.98	<2		
89.46	26.47	<3	84.69	32.50	<3	MED RESOL 75-100 LP/MM	MED CONTRAST
92.77	27.63	<3	96.90	30.55	<3		
81.30	24.20	<3	85.81	36.48	<3		LOW CONTRAST
98.81	26.23	<3	89.29	23.70	<3		
137.53	72.35	<4	147.36	61.59	<4	HIGH RESOL ≥100 LP/MM	MED CONTRAST
111.98	59.34	<4	86.44	25.26	<3		
114.28	69.30	<5	114.58	67.72	<5		LOW CONTRAST
120.79	58.39	<4	117.89	57.02	<4		

bar reading method and the results were independent of contrast and resolution value. Using the edge method, they deviated less than three elements for resolutions to 100 line pair/mm and the results again were independent of contrast. In the high resolution area (above 100 lines pair/mm), the edge gradient method had maximum deviations equivalent to five elements. This is a resolution difference of four elements between the three bar method and the edge method for the worst case. From this it appears that the edge method gives reasonable correlation for targets with resolution values less than 100 line pair/mm when comparing the average values by both methods.

The performance of the individual observers was investigated to determine if a particular reader's data were biased or incorrect. Table 3 lists the experience of each observer and the number and percentages of times that he recorded either the highest or the lowest reading of the group on a particular target. Ties counted for all observers. From this brief look, no pattern is evident that substantiates inconsistencies of any individual's data.

The results of our expert reader over the total 90 targets are displayed in Table 4. The results showed good correlation between edge gradient three bar target results in most cases. One set of low resolution color film specimens was also examined by our expert reader. The results comparing the two methods were extremely close as shown in Table 5. The corresponding standard deviations for the color imagery were 3.97 and 4.58 for edge versus 4.24 and 4.32 for the three bar method. This is less than one resolution target element error between the average readings.

TABLE 3

OBSERVER EVALUATION

EDGE METHOD

READER #	# TIMES HIGH/%	# TIMES LOW/%	READER EXPERIENCE
1	2-6.5	0-0	6 yrs
2	2-6.5	0-0	12 yrs
3	2-6.5	12-44.4	12 yrs
4	7-22.6	0-0	8 yrs
5	1-3.2	0-0	5 yrs
6	4-12.9	5-18.5	2 yrs
7	12-38.7	0-0	20 yrs
8	1-3.2	3-11.1	0 yrs
9	0-0	7-25.9	0 yrs

3 BAR METHOD

1	2-5.1	2-4.9	6 yrs
2	3-7.7	2-4.9	12 yrs
3	4-10.3	3-7.3	12 yrs
4	2-5.1	11-26.8	8 yrs
5	9-23.1	0-0	5 yrs
6	11-28.2	3-7.3	2 yrs
7	3-7.7	9-22.0	20 yrs
8	1-2.6	5-12.2	0 yrs
9	4-10.3	5-12.2	0 yrs

TABLE 4

EXPERT OBSERVER READINGS (LP/mm)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
SAMPLE #	TGT. #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	SAMPLE #	TGT. #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
#1	1	64.0	57.0	75.0	60	#5	1	72	72	38	60
	2	143.0	114.0	150.	85		2	72	72	60	67
	3	128.0	114.0	150	95		3	90	90	67	67
	4	128.0	114.0	134	107		4	90	90	67	60
	5	128.0	128.0	134	134		5	81	72	75	42
	6	114.0	114.0	107	95		6	81	72	75	47
	7	64.0	57.0	60	53		7	64	64	53	53
#2	1	72	51	60	34	#6	1	40	32	27	42
	2	128	72	119	75		2	45	40	38	42
	3	128	72	119	95		3	57	64	38	53
	4	128	81	95	95		4	64	64	53	53
	5	128	81	95	85		5	72	72	75	67
	6	90	81	95	75		6	72	72	75	85
	7	64	72	34	53		7	72	72	95	85
#3	1	90	81	85	85	#7	1	64	64	47	42
	2	81	101	95	95		2	72	57	53	27
	3	128	128	119	119		3	64	64	53	34
	4	128	90	95	85		4	72	72	95	60
	5	81	90	47	75		5	90	81	95	67
	6	72	81	30	47		6	90	72	85	67
	7	57	57	30	30		7	57	64	47	67
#4	1	72	64	75	67	#8	1	72	40	75	27
	2	114	72	134	75		2	72	40	85	34
	3	114	102	107	107		3	81	57	75	42
	4	102	90	95	95		4	90	72	95	47
	5	72	57	60	47		5	90	81	85	75
	6	81	64	53	47		6	102	72	107	75
	7	45	45	53	30		7	102	72	107	75

TABLE 4 (Cont'd)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
SAMPLE #	TGT. #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	SAMPLE #	TGT. #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
#9	1	81	81	95	67		13	64	64	53	67
	2	128	128	150	119		14	72	81	85	67
	3	143	143	190	150		15	81	90	95	95
	4	128	128	170	150		16	90	90	75	75
	5	114	128	179	119		17	64	64	53	38
	6	64	64	53	42		18	90	90	107	107
	7	45	45	34	27						
#10	1	102	102	119	107		1				
	2	128	128	134	134		2				
	3	143	128	150	150		3				
	4	143	114	134	134		4				
	5	72	72	75	95		5				
	6	51	64	38	75		6				
	7	40	40	30	30		7				
#11	1	114	114	134	107		1				
	2	143	143	170	170		2				
	3	143	114	150	150		3				
	4	102	45	134	119		4				
	5	57	40	107	95		5				
	6	40	45	53	75		6				
	7	32	45	42	53		7				
#12	1	114	143	95	150		1				
	2	143	114	169	150		2				
	3	143	114	150	95		3				
	4	114	90	119	102		4				
	5	102	64	67	95		5				
	6	72	57	53	75		6				
	7	57	36	24	42		7				

TABLE 5

EKTACHROME IMAGERY RESOLUTION READING (LP/mm)

		RESOLUTION L/mm						RESOLUTION L/mm			
		EDGE METHOD		THREE-BAR METHOD				EDGE METHOD		THREE-BAR METHOD	
TGT. #	FRAME #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL	TGT. #	FRAME #	RADIAL	TANGENTIAL	RADIAL	TANGENTIAL
1	1	45.1	45.1	40.4	35.6						
	2	40.3	35.8	35.6	32.0						
2	1	40.3	40.3	35.6	35.6						
	2	40.3	40.3	35.6	32.0						
	3	45.1	45.1	40.4	40.4						
3	1	45.1	40.3	45.2	40.4						
	2	45.1	45.1	45.2	40.4						
	3	40.3	40.3	35.6	32.0						
4	1	45.1	45.1	45.2	40.4						
	2	45.1	45.1	40.4	40.4						
	3	45.1	45.1	45.2	40.4						
	4	40.3	40.3	40.4	40.4						
	5	35.8	35.8	40.4	40.4						
5	1	45.1	45.1	35.6	35.6						
	2	35.8	32.0	32.0	32.0						
	3	35.8	32.0	35.6	28.4						
6	1	45.1	40.3	45.2	35.6						
	2	45.1	40.3	40.4	40.4						
	3	45.1	40.3	40.4	35.6						
7	1	45.1	40.3	45.2	40.4						
	2	45.1	45.1	45.2	40.4						
	3	45.1	45.1	45.2	40.4						
8	1	40.3	32.0	40.4	28.4						
	2	32.0	32.0	32.0	32.0						
	3	35.8	40.3	40.4	35.6						
9	1	45.1	45.1	40.4	45.2						
	2	45.1	45.1	45.2	40.4						
	3	40.3	40.3	40.4	35.6						

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

One objection everyone made about the instrument was that the three bar targets used on the microscope reticle masked the photographic edges to be measured. It is recommended that another reticle be incorporated in the device instead of the three bar targets. For example, a crosshair reticle with hatch markings corresponding to direct resolution values could be incorporated in the device. With this method, one side of the estimated edge would be aligned and parallel and coinciding with one axis of the crosshair. The resolution is read at the point on the reticle scale where the other estimated side of the edge crosses the other axis.

The results are generally encouraging, indicating that photographic system resolution measurements using the edge gradient technique tend to satisfy MSgt. Pollizzi's criteria. The measuring microscope edge gradient method yields reasonably accurate results particularily when used on B&W film targets with resolution of less than 100 line pair/mm, and for color film in the 30-50 lp/mm range. This range was the only one tested using color film.

Improvements in the system such as changing the edge matching recticle, the installation of a fine focus along with a rigid mount, an eye piece to eliminate head motion, and an increased amount of personnel training should provide the field user a capability to determine the approximate resolution of operation imagery.